# 20. THE PHILIPPINE PROGRAM IN BREEDING FOR RESISTANCE TO DOWNY MILDEW OF MAIZE

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## Introduction

The downy mildew disease of maize is endemic to the Philippines. However, records show that formal breeding for rsistance to this disease started only in 1953 (Aquilizan, 1960 and Santos and Aquilizan, 1961). A disease outbreak which occurred during the 1953 wet season at the Central Experiment Station, University of the Philippines at Los Baños made both plant breeders and pathologists focus more attention towards its control from them on. More efforts were exerted through the years as the disease was realized to be one of the primary limiting factors on production.

Breeding for downy mildew resistance of maize in the Philippines may be roughly divided into four periods:

a. Selection and isolation of downy mildew resiistant inbred lines (1953–1963).

b. Screening for downy mildew resistance among local and introduced varieties (1964–1968).

c. Varietal hybridization between local downy mildew resistant sources and high yielding introduced germplasm and subsequent development of the Philippine DMR's (1966–1973).

d. Intarpopulation improvement of composite populations for downy mildew resistance and other good agronomic characters (Current).

## Selection and Isolation of DMR Inbred Lines (1953–1963)

During this period the corn breeding program at College of Agriculture, UPLB was following the inbred-hybrid approach. During the 1953 wet season hundreds of locally developed and introduced inbred lines were grown by Drs. H. K. Hayes and D. L. Umali in the Central Experiment Station. A severe epiphytotic of downy mildew occurred during the season and Dr. G. C. Kent, then visiting professor in plant pathology, classified the different lines as follows:

*Highly Resistant*—lines showing from 1 to 25 per cent infection (12 lines).

*Resistant*—lines showing from 26 to 50 per cent infection (37 lines).

*Moderately Resistant*—lines showig 51 to 75 per cent infection (102 lines).

*Susceptible*—lines showing over 75 per cent infection (518 lines).

Surviving or "downy mildew free" plants in this nursery were either selfed or sibbed.

Downy mildew screening nurseries were set-up during the succeeding seasons where surviving plants were either selfed or sibbed (Aquilizan, 1960). In-charge were I. S. Santos and O. Q. Ballesteros. These nurseries were planted later than the regular crop using Cuban Yellow Flint, a susceptible variety as spreader rows. These nurseries had a disadvantage in that they were highly dependent on the climate and amount of inoculum available from the surrounding fields since no artificial inoculations were done.

In 1957, F. A. Aquilizan, a plant pathologist, was made in-charge of the nursery.

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In the 1958 wet season F. A. Aquilizan and I. S. Santos enhanced epiphytotic conditions in the nursery by artificial inoculation of conidial suspension and more frequent planting of spreader rows. Infection ranged from 0–100 per cent, with an over-all mean of about 54 per cent. Inspite of the fact that most of the materials planted in this 1958 wet season had undergone at least one season of selection against downy mildew, the over-all mean percentage was still about 14 per cent more than that of the 1956 wet season or 1956–57 dry season.

During the 1959 wet season, only selfed or sibbed materials from rows exhibiting less than 30 per cent infection in the 1958 nursery were planted and an over-all mean of 15 per cent was obtained indicating progress in selection (Aquilizan, 1960). The lines or sublines having 9 per cent or less infection were classified as truly resistant and most were derived from local varieties. Included among these were some sublines from *Scl. maydis* R1w and *Scl. maydis* R3YY, the *Sclerospora maydis* (Rac.) Butler resistant inbred lines introduced from Indonesia.

Initial crosses were made in 1960 (Aquilizan and Santos, 1961 and Payson et al., 1962) for the production of downy mildew resistant hybrids and synthetic varieties. However, no datum was reported on the yield performance and downy mildew reaction of the resulting hybrids.

Yield and downy mildew reaction of derived DMR synthetics together with 10 synthetiics from India and 4 recommended Phillippine Hybrids were reported by Paule (1963). Synthetic varieties derived from Philippine DMR lines gave a range of 4.2 to 21.7 per cent infection, the Indian Synthetics showed from 15.2 to 48.0 per cent infection and the Philippine Hybrisd, from 25.2 to 54.0 per cent infection. College Yellow Flint had an infection of 24.7 per cent. In terms of yield seven out of the 10 Indian Synthetics were among the top 10 entries, the highest yield being 4.54 tons per hectare. The highest yielder among the locally derived DMR synthetics ranked 14th with a mean yield of 3.37 tons per hectare. This may be attributed to the fact that the inbred lines composing the synthetics were of local orign and therefore little heterosis may be expected. The Indian Synthetics which were resistant to downy mildew species in India were introduced to the Philippínes by Dr. S. Wortman in 1961.

Studies on the inheritance of resistance to downy mildew disease was made possible

**Table 1. Downy mildew mean infection (per cent) in parental inbreds and in their $F_1$, $F_2$ and backcross generations ($BC_1$) in the 1962 wet season at College, Laguna (Gomez, et al., 1963)**

| Crosses | Susceptible Parent | BC to Sus. Parent | $F_1$ | $F_2$ | BC to Res. Parent | Resistant Parent |
|---|---|---|---|---|---|---|
| Ph9 dm R9×Sg1533 | 85 | 60 | 39 | 38 | 9 | 43 |
| A216 dm R1×Sg1533 | 92 | 54 | 49 | 34 | 18 | 24 |
| A216 dm R2×Sg1533 | 88 | 40 | 39 | 33 | 24 | 18 |
| A217 dm R1×Sg1533 | 88 | 73 | 52 | 35 | 23 | 35 |
| CYF dm R1×Sg1533 | 92 | 63 | 64 | 50 | 42 | 42 |
| AY7 dm R1×1533 | 90 | 65 | 51 | 60 | 42 | 44 |
| Ph4×Ph7 | 58 | 46 | 30 | 24 | 24 | 21 |
| Ph4×F44 | 64 | 45 | 40 | 35 | 17 | 36 |
| Ph4×Sg18 | 100 | 91 | 63 | 47 | 36 | 55 |
| Ph4×Sg1533 | 85 | 81 | 49 | 55 | 15 | 21 |
| Ph4×SA24 | 85 | 70 | 49 | 52 | 17 | 32 |
| Mean | 34 | 84 | 47 | 42 | 24 | 63 |

with the isolation of the resistant inbred lines (Gomez et al., 1963 and Payson, 1965). Gomez et al. (1963) suggested that resistance may be partially dominant and that only a few factor pairs control the reaction of corn to the disease (Table 1). They indicated, however, that the results obtained were inadequate to separate the direct effect of genes on resistance or susceptibility from the indirect effect of plant vigor.

Screening and selection of downy mildew resistant inbred lines continued until 1963. An important accomplishment during this period is the development of the new widely used resistant inbred lines, A206 DMR and Ph9 DMR. Screening tests conducted during the 1964 and 1965 wet seasons (Table 2) showed that A206 DMR and Ph9 DMR consistently gave resistant reaction to the disease.

**Table 2. Per cent downy mildew infection among Philippine DMR inbred lines (after Mercado, et al., 1966)**

| Entry | 1964 | | 1965 | |
|---|---|---|---|---|
| | No. of Plants Observed | Per cent Infection | No. of Plants Observed | Per cent Infection |
| Ph9 DMR | 340 | 7.4 | 870 | 20.1 |
| A206 DMR | 334 | 9.0 | 1,135 | 7.5 |
| Phlb DMR | 363 | 12.4 | 970 | 35.0 |
| Ph7 DMR | 373 | 12.6 | — | — |
| Tuxpeño (Comp. de Comp.) | 424 | 78.5 | 667 | 75.3 |

## Screening for DMR Among Local and Introduced Germplasm (1964-1968)

In 1963, a major review on the breeding program was undertaken. It was observed that the hybrid program had little impact on corn production in the Philippines and that this was primarily due to the difficulty in seed production and distribution. As a result of the review, the program was reoriented towards the development of high yielding open-pollinated varieties (Mercado, et al. 1964).

In 1963, a large number of varieties and composites from the Maize Program of the Rockefeller Foundation in Mexico were tested for general adaptability and yielding potential. These were also included in the downy mildew nursery from the 1964 wet season (Mercado, et al. 1966). Downy mildew-free plants were sibbed within each entry. Bulk seeds were planted in the succeeding nursery. Such procedure was adopted with the hope of increasing the gene frequency for resistance through simple mass selection and at the same time identify the good sources of resistance.

Infection among the test materials planted in 1964 ranged from 4.0 to 87.8 per cent with a mean of 42.8 per cent. In 1965, per cent infection ranged from 7.5 to 98.5 with a mean of 69.8 per cent. No. datum was obtained during the 1966 wet season at Los Baños. The same materials planted in Ilagan, Isabela during the same season gave a range of 29.7 to 91.7 per cent infection with a mean of 73.2 per cent. In all these tests, only the native varieties gave consistently resistant reaction to the disease. Table 3 presents the per cent infection of the native varieties.

From these studies, Mercado et al. (1966) observed that only a few selected local accessions were potential sources of downy mildew resistance.

It is interesting to note that the native yellow flints are not as resistant as any of the white flints. Since more than 80 per cent of the corn produced in the Philippines is white corn, the white varieties are grown in areas where downy mildew has long been

**Table 3. Per cent downy mildew infection among native varieties (after Mercado, et al., 1966)**

| Entry | Los Baños | | Ilagan | Mean |
|---|---|---|---|---|
| | 1964 WS | 1965 WS | 1966 WS | |
| Aroman White Flint | 7.0 | 13.5 | 45.5 | 22.0 |
| Bukidnon White Flint | 4.0 | 31.4 | 49.3 | 28.2 |
| Cebu White Flint | 7.6 | 26.9 | 43.1 | 25.9 |
| Kabacan White Flint | 9.7 | 18.3 | 64.5 | 30.8 |
| Tiniguib | 24.6 | 26.4 | 42.3 | 31.1 |
| Bicol White Flint | 25.0 | 26.3 | 54.5 | 35.3 |
| Cadlan White Flint | 19.6 | 36.0 | 51.4 | 35.7 |
| College White Flint | 13.3 | 43.7 | 78.7 | 45.2 |
| Davao Yellow Flint | 34.8 | 62.3 | 63.5 | 53.5 |
| College Yellow Flint | 34.8 | 61.4 | 81.7 | 59.3 |
| (CW×Tuxpeño)# | 15.3 | 72.3 | 71.9 | 53.2 |
| Mean[1)] | 42.8 | 69.8 | 73.2 | 61.9 |

1) Mean of all entries

known to exist. Therefore, they have undergone several years of natural selection against this disease.

A new batch of introduced varieties from Mexico were screened during the 1967 wet and 1967–68 dry seasons. Downy mildew screening nurseries were set up in Los Baños, MIT, Cotabato and BPI, Aroman, Cotabato (Carañgal et al., 1968 and Carañgal et al., 1971). Two newly collected native varieties were found to be highly resistant to downy mildew. These are Mimies White Flint and MIT Sel. 2. MIT Sel. 2, as the name implies, was developed by the corn breeders of the Mindanao Institute of Technology (Marasigan, 1973 and Marasigan and dela Cruz 1969).

The downy mildew screening work conducted during this period is summarized in Table 4.

**Table 4. Summary of varietal screeing for downy mildew resistance from 1964 to 1968**

| Location | Year | No. of Entries | Range of Infection (%) | Mean Per cent Infection |
|---|---|---|---|---|
| Los Baños | 1964 WS | 102 | 4.0– 87.8 | 42.8 |
| Los Baños | 1965 WS | 86 | 7.0– 98.5 | 69.8 |
| Ilagan | 1966 WS | 49 | 26.4– 94.2 | 73.2 |
| Los Baños | 1967 WS | 92 | 8.0–100 | 90.5 |
| Aroman | 1967–68 DS | 104 | 2.0– 84.0 | 55.9 |
| MIT | 1967–68 DS | 97 | 6.0– 88.0 | 50.9 |

Also during this period, Francis (1967) reported a genetic study of downy mildew resistance using four introduced varieties from Mexico and PH 1b DMR. Table 5 presents the per cent downy mildew infection of his materials. Francis concluded that resistance to downy mildew in maize was a quantitative trait which followed an additive pattern of inheritance because of the facts that the filial generations were intermediate between

**Table 5. Downy mildew infection in populations of parents, crosses and backrosses of four families (after Francis, 1967)**

| Family | $P_{sus}$ | $BC_{2sus}$ | $BC_{1sus}$ | $F_1F_2$ | $BC_{1res}$ | $BC_{2res}$ | $P_{res}$ |
|---|---|---|---|---|---|---|---|
| November-Decembe, 1965 | | | | | | | |
| Antigua | 100 | 100 | 100 | 99 | 96 | 80 | 87 |
| Puerto Rico | 100 | 99 | 99 | 98 | 94 | 82 | 87 |
| Tuxpeño | 100 | 98 | 99 | 96 | 95 | 84 | 87 |
| Mariño | 99 | 93 | 98 | 97 | 94 | 83 | 87 |
| Average | 100 | 98 | 99 | 97 | 94 | 83 | 87 |
| December, 1965-February, 1966 | | | | | | | |
| Antigua | 100 | 98 | 99 | 97 | 86 | 82 | 72 |
| Puerto Rico | 100 | 99 | 99 | 96 | 89 | 83 | 79 |
| Tuxpeño | 100 | 100 | 99 | 94 | 90 | 81 | 73 |
| Mariño | 100 | 99 | 98 | 94 | 85 | 82 | 75 |
| Average | 100 | 99 | 99 | 95 | 88 | 82 | 76 |
| January-April, 1966 | | | | | | | |
| Antigua | 51 | 51 | 45 | 26 | 14 | 7 | 6 |
| Puerto Rico | 40 | 36 | 28 | 16 | 11 | 9 | 6 |
| Tuxpeño | 45 | 38 | 30 | 29 | 16 | 9 | 6 |
| Mariño | 42 | 37 | 30 | 17 | 13 | 10 | 6 |
| Mean | 44 | 40 | 33 | 22 | 14 | 9 | 6 |
| Mean of Three Plantings | | | | | | | |
| Antigua | 83.67 | 83.00 | 81.33 | 74.00 | 65.34 | 56.34 | 56.00 |
| Puerto Rico | 80.00 | 78.00 | 75.34 | 70.00 | 64.67 | 58.00 | 57.34 |
| Tuxpeño | 81.67 | 78.67 | 76.00 | 73.00 | 67.00 | 58.00 | 55.34 |
| Mariño | 80.34 | 76.34 | 75.34 | 69.34 | 64.00 | 58.34 | 56.00 |
| Average | 81.33 | 79.00 | 77.00 | 71.34 | 65.34 | 58.00 | 56.34 |

the two parents, the two backcross generations to both parents were intermediate between the parents and the $F_1$.

## Varietal Hybridization Between Local Downy Mildew Resistant Sources and High Yielding Introduced Germplasm and Subsequent Development of the Philippine DMRs (1967-1973)

As was repeatedly observed during the two earlier periods, introduced varieties were susceptible to the downy mildew disease in the Philippines. Selections made from these varieties by sibbing "downy mildew free" plants in the nurseries did not result to any observable progress in terms of resistance to the disease.

It has also been well documented during these periods that a number of native varieties and inbred lines are good sources of resistance to this disease. This is expected since these varieties have been exposed to downy mildew for several decades or even cnturies. Natural selection have played a big role in the evolution of these downy mildew resistant native varieties. However, these native varieties have very poor grain yield potentials. To develop high yielding downy mildew resistant varieties, hybrids between the native DMRs and the high yielding introduced varieties should be made and this followed by selection for downy mildew resistance, grain yield and other characters in suceeding generations.

Carañgal et al., (1968) started making these crosses in 1967 dry season. MIT S-2, Ph 9 DMR, A 206 DMR, Aroman White Flint and Tiniguib were used as resistant parents in crosses with several high yielding introduced varieties and composites. The $F_1$'s and $F_2$'s were entered in yield trials in 1967 wet and 1967–68 dry seasons and compared with the recommended varieties (Carañgal et al., 1971). Based on the results of these trials, twelve advanced generation hybrids between native and introduced germplasm were selected, and then screened for downy mildew resistance in Aroman, Cotabato during the 1969 wet season. The per cent downy mildew infection of these populations are shown in Table 6. From this test, 10 populations were selected for further improvement while the two others, (MIT × Tuxpantigua)# and (Guatemala × A206 DMR)# were discarded because of high per cent infection.

**Table 6. Per cent infection of different populations evaluated in Aroman Experiment Station (Carañgal et al., 1971)**

| Entry No. | Populations | Total No. of Plants | No. of Infected Plants | % Infection |
|---|---|---|---|---|
| 1 | College White × Tuxpeño | 1,224 | 287 | 23 |
| 2 | MIT × Cuba Gpo. 1 | 788 | 121 | 15 |
| 3 | MIT × Flint Composite Amarillo | 801 | 204 | 25 |
| 4 | MIT × Eto Amarillo | 717 | 202 | 28 |
| 5 | MIT × Tuxpantigua | 546 | 456 | 84 |
| 6 | MIT × Cupurico | 512 | 206 | 40 |
| 7 | [(College White × Tuxpeño) × Aroman White Flint] | 792 | 211 | 27 |
| 8 | UPCA Var 4 × Aroman White Flint | 872 | 184 | 21 |
| 9 | Columbia 2 × Aroman White Flint | 717 | 143 | 20 |
| 10 | Eto Blanco × Aroman White Flint | 783 | 337 | 43 |
| 11 | UPCA Var 4 × Cebu White Flint | 778 | 142 | 18 |
| 12 | Guatemala × A206 DMR | 482 | 273 | 57 |
| 13 | Sweet Corn | 624 | 395 | 63 |

The survivors in each of the 10 selected populations were selfed. Replicated $S_1$ progeny test for downy mildew resistance was conducted during 1969–70 dry season at Aroman, Cotabato. Surviving plants from selected rows in each population were chain crossed for recombination.

The recombined populations together with their original population were screened during the 1970 wet season to determine whether the selection scheme was effective. The screening test was done in three locations using randomized block design with 2 replications. Per cent infection in three locations are shown in Table 7. For the Musuan test, improvement was observed in all populations although only five comparisons showed significant improvement. The highest improvement was obtained with Eto Blanco × Aroman WF. All derived populations were significantly better than the recommended UPCA VAR's and the sweet corn check. The test at Los Baños was not as good as that at Musuan. The sweet corn susceptible check showed only 39 per cent infection. Some derived populations showed improvement over their original counterparts. However, the improvements were not significant. Severe epiphytotics were observed in Ilagan, The sweet corn check showed 100 per cent infection. The lowest infection among the

**Table 7. Percent downy mildew infection of original and derived populations and checks at Musuan, Bukidnon; College, Laguna; and Ilagan, Isabela during the 1969 wet season (Carañgal et al, 1970)**

| Entry No. | Pedigree | Musuan Bukidnon | Los Baños Laguna | Ilagan Isabela | Mean | % Observed Gain |
|---|---|---|---|---|---|---|
| 1 | (CW×Tuxpeño)# | 35 | 32 | 91 | 52.67 | |
| 2 | (CW×Tuxpeño)DMR | 13 | 21 | 74 | 36.00 | 31.64 |
| 3 | (MIT×Cuba Gpo. 1)# | 27 | 21 | 78 | 42.00 | |
| 4 | (MIT×Cuba Gpo. 1)DMR | 17 | 16 | 70 | 34.37 | 18.26 |
| 5 | (MIT×Flint Comp. Amar)# | 20 | 21 | 88 | 43.00 | |
| 6 | (MIT×Flint Comp. Amar)DMR | 12 | 23 | 57 | 30.67 | 28.67 |
| 7 | (MIT×Eto Amarillo)# | 28 | 26 | 76 | 43.33 | |
| 8 | (MIT×Eto Amarillo)DMR | 12 | 20 | 67 | 33.00 | 23.84 |
| 9 | (MIT×Cupurico)# | 25 | 8 | 68 | 33.67 | |
| 10 | (MIT×Cupurico)DMR | 16 | 15 | 57 | 29.33 | 12.88 |
| 11 | (Eto Blanco×Aroman WF)# | 68 | 43 | 89 | 66.67 | |
| 12 | (Eto Blanco×Aroman WF)DMR | 12 | 15 | 66 | 31.00 | 53.50 |
| 13 | [(CW×Tuxpeño)×Aroman WF)# | 33 | 16 | 72 | 40.33 | |
| 14 | [(CW×Tuxpeño)×Aroman WF]DMR | 14 | 18 | 73 | 35.00 | 13.21 |
| 15 | (UPCA Var 4×Cuba WF)# | 37 | 16 | 81 | 44.67 | |
| 16 | (UPCA Var 4×Cuba WF)DMR | 16 | 27 | 70 | 37.67 | 15.67 |
| 17 | (Colombia 2×Aroman WF)# | 22 | 19 | 62 | 34.33 | |
| 18 | (Colombia 2×Aroman WF)DMR | 18 | 20 | 78 | 38.67 | −12.64 |
| 19 | (UPCA Var 2×Aroman WF)# | 21 | 24 | 85 | 43.33 | |
| 20 | (UPCA Var 2×Aroman WF)DMR | 15 | 22 | 85 | 40.67 | 6.13 |
| 21 | A206 DMR | 4 | 19 | 26 | 16.33 | |
| 22 | Aroman WF | 4 | 14 | 28 | 15.33 | |
| 23 | UPCA Var 1 | 74 | 40 | 99 | 71.00 | |
| 24 | UPCA Var 2 | 47 | 37 | 81 | 55.00 | |
| 25 | UPCA Var 4 | 46 | 36 | 97 | 59.67 | |
| 26 | Popcorn Syn. | 71 | 52 | 92 | 73.67 | |
| 27 | Sweet Corn Syn. | 49 | 39 | 100 | 62.67 | |
| | Mean of Original | 31.6 | 22.6 | 79.0 | 44.40 | |
| | Mean of derived DMR | 14.5 | 19.7 | 69.7 | 34.63 | 22.0 |

different populations was 57 per cent compared to the resistant checks of 28 per cent for Aroman WF and 26 per cent for A206 DMR. The improved populations were consistently better than the original populations.

By combining data from all locations and populations an average gain in selection of 22.00 per cent was obtained. This gain is attribtued to the following cycles of selection.

1. One cycle of mass selection when surviving plants were self pollinated to produce the $S_1$ progenies.
2. One cycle of among and within $S_1$ line selection.

Based on these screening tests and regional yield trials conducted in several locations, (College White × Tuxpeño) DMR, (MIT × Cuba Gpo. 1) DMR, (MIT × Flint Comp. Amar) DMR, (MIT × Cupurico) DMR and (Eto Blanco × Aroman WF) DMR were selected for further improvement (Claudio, 1972). Yellow and white kernels were sepa-

**Table 8. Pedigree of the Philippine DMR's**

| | Original Pedigree |
|---|---|
| Philippine DMR 1[1)] | (MIT×Cuba Gpo. 1) DMR |
| Philippine DMR 2 | (CW×Tuxpeño) DMR |
| Philippine DMR 3 | (MIT×Flint Comp. Amar.) DMR |
| Philippine DMR 4 | (MIT×Flint Comp. Amar.) DMR |
| Philippine DMR 5 | (MIT×Cupurico) DMR |
| Philippine DMR 6 | (Eto Blanco×Aroman WF) DMR |
| Philippine DMR 8 | (MIT×Cupurico) DMR |
| Philippine DMR 10 | (MIT×Cuba Gpo. 1) DMR |

1) Odd numbers are assigned to varieties with yellow endosperm and even numbers to varieties with white endosperm

rated in (MIT × Cuba Gpo. 1) DMR, (MIT × Flint Comp. Amar) DMR and (MIT × Cupurico) DMR. These derived populations were then given Philippine DMR numbers as shown in Table 8.

Bulk seed of these Philippine DMRs were planted during the 1970–71 dry season at Aroman, Cotabato. Surviving plants were selfed for another cycle of $S_1$ progeny selection. The yellow Philippine DMRs were "purified" by recombining ears that did not segregate into white and yellow kernels.

The Philippine DMRs were included in the advanced variety testing program, in provincial variety trials, in farmers' trials and also in the IACP DMR Variety Trials. Based on these tests, Philippine DMR 2 and MIT Sel-2 were recommended to the Philippine Seed Board for release to farmers in 1971. Philippine DMR 1 became a Seed Board variety in 1973.

During this period, several more hybrids between DMR sources and promising introduced varieties and composites were made. This massive varietal hybridization program was made possible through the smooth exchange of breeding materials among IACP member countries and CIMMYT.

The basic strategy for the development of DMR varieties is to grow $F_1$ and $F_2$ plants for seed production in downy mildew free conditions. Bulked $F_2$ seeds are entered in preliminary yield trials and in downy mildew screening nurseries. In the downy mildew screening nurseries, surviving plants in each cross are sib-mated and bulked. High yielding and downy mildew resistant advanced generation hybrids are selected for further screening.

## Intra-Population Improvement Among Composite Populations (Current)

The recommended downy mildew resistant varieties, Philippine DMR 1 and 2 and MIT Sel-2, are at present widely grown in the Philippines. This was made possible through intensive seed production and distribution and extension services of the national government. However, this initial success gives the breeders only a short breading spell. Present goals are aimed at achieving not only higher downy mildew resistance and yield levels, but also resistance to other diseases and pests such as leaf blight, rust, stalk rot, corn borer and weevil, early maturity, good standability, and high protein quality.

Starting with the 1973 wet season crop, several varieties and composites were grouped according to a predominant desirable character (Aday et al., 1973) in addition to downy mildew resistance. The varieties or composites in each group were intermated by plant-to-plant sibbing. Each group was then treated as a single core or base population from which further improvement through recurrent selection will be obtained.

About 8,000 ears were harvested from the 1973 wet season crop. Each ear was considered a full-sib family. These were planted in ear-rows at UP La Granja Research and Training Station in La Carlota City and in the UP-CMU Downy Mildew Screening Nursery in Musuan during the 1973–74 dry season. Rows were selected based on per cent downy mildew infection, days to silking, plant and ear height, effective number of ears per plant, standability; and leaf disease, stalk rot and borer ratings. Selected rows were inter-pollinated through full-sib or plant-to-plant mating. This procedure allowed further blending among superior genotypes in each population. Remnant seeds of selected families which were missed during pollination at La Granja and Musuan were planted during the 1974 off-season nursery (January–April) at Los Baños for recombination.

The initial plan was to pursue such modified full-sib family selection scheme but because of the unexpected increase in prices due to the oil crisis we shifted to the modified ear-to-row or among-and within-half-sib family selection after considering the following practical advantages that could be derived from this scheme:

1. Among the intra-population improvement methods already developed, this method gives one of the highest expected genetic improvement per cycle of selection. There are two stages of selection: among rows, and among plants within selected rows. Additional efficiency is otbained by roguing the male rows. We complete one cycle of selection in one season.

2. The crossing block eliminates hand pollination. Also, open-pollinated ears are more fully developed compared with hand-pollinated ears. This allows us to select for ear size. In addition, more seeds could be harvested for use in experimental variety trials and correlated agronomic studies and as direct source of breeder seeds for foundation seed production.

3. Selection is made at harvest time. This gives us ample time for analyses of protein, lysine and tryptophan content and for weevil infestation, as well as for interpretation of the data before the next planting.

4. Incorporation of new germplasm sources in the population is easy. Any new promising germplasm source needs only to be planted in the crossing block as female rows. Such practice would allow us to continuously get some improvement through several cycles of selection.

This method is not without disadvantages and they are:

1. It requires an additional space for planting the male rows. However, the additional area is only about ⅛ of that developed to the regular ear-to-row, full sib family or $S_1$ progeny selection method.

2. It requires isolation lots. We solved this easily by modifying the field layout and by time isolation.

At present, we have constituted the following core populations.

1. Philippine DMR Composite 1—composed o fPhilippine DMR 1, 3, and 5 and (Metro × MIT) DMR.

2. Philippine DMR Composite 2—composed of MIT Sel-2, Philippine DMR 2, 4, 6 and 10, Chain-cross DMR.

3. Philippine DMR Composite 3—composed of several promising advanced generation hybrids of Philippine DMRs × introduced varieties.

4. Philippine DMR Composite 4—white version of Philippine DMR Composite 3.

5. Caribbean Comp. DMR—composed of full-sib families developed from selected $S_1$ lines of the IACP Regional DMR progeny test.

**Table 9. Frequency distribution an average per cent infection of different DMR composite during the 1974 wet season at CMU**

| Pedigree | 0–10 | 11–20 | 21–30 | 31–40 | 41–50 | 51–60 | 61–70 | 71–80 | 81–90 | 91–100 | Total No. Families | Mean | Mean of Sus. Check[1] | Mean Resistant Check[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phil. DMR Comp. 1[3] | 23 | 21 | 33 | 50 | 63 | 40 | 42 | 26 | 9 | 5 | 312 | 44.4 | 92.0 | 43.7 |
| Phil. DMR Comp. 2[3] | 135 | 116 | 60 | 40 | 12 | 11 | 8 | 2 | 0 | 5 | 380 | 17.9 | 94.8 | 16.2 |
| Phil. DMR Comp. 3 | 101 | 158 | 116 | 76 | 51 | 20 | 13 | 6 | 0 | 0 | 541 | 24.1 | 49.2 | 14.3 |
| Phil. DMR Comp. 4 | 35 | 71 | 62 | 30 | 30 | 12 | 7 | 6 | 1 | 0 | 254 | 26.2 | 56.7 | 7.8 |
| Caribbean Comp. DMR | 30 | 47 | 40 | 43 | 23 | 20 | 12 | 8 | 2 | 2 | 208 | 29.1 | 79.4 | 22.7 |
| CB-W-DMR Comp. 1 | 53 | 128 | 187 | 139 | 97 | 55 | 23 | 5 | 2 | 0 | 689 | 30.7 | 51.0 | 18.6 |
| CB-W-DMR Comp. 2 | 16 | 13 | 20 | 10 | 16 | 7 | 8 | 6 | 0 | 0 | 96 | 32.8 | 57.3 | 18.2 |
| Early DMR Comp. 1 | 147 | 73 | 29 | 8 | 3 | 2 | 1 | 0 | 0 | 0 | 263 | 11.4 | 49.8 | 6.5 |
| Early DMR Comp. 2 | 46 | 66 | 27 | 13 | 4 | 3 | 1 | 1 | 0 | 0 | 160 | 17.5 | 37.8 | 7.3 |
| Prolific DMR Comp. 1 | 79 | 95 | 70 | 39 | 21 | 9 | 4 | 4 | 0 | 0 | 321 | 21.1 | — | 5.9 |
| Prolific DMR Comp. 2 | 38 | 40 | 32 | 18 | 15 | 9 | 2 | 1 | 1 | 0 | 156 | 23.3 | — | 3.7 |
| Brachytic DMR Comp. | 51 | 79 | 65 | 49 | 25 | 9 | 6 | 4 | 2 | 1 | 291 | 25.0 | — | 9.2 |
| Phil. DMR Opaque Comp. 1 | 57 | 87 | 61 | 42 | 22 | 14 | 3 | 4 | 4 | 1 | 297 | 24.5 | — | 10.7 |

1) UPCA Var 1
2) MIT Sel. 1 for the whites and Phil. DMR 1 for the yellows
3) Twice inoculated

6. Corn Borer-Weevil-DMR Comp. 1—composed of selected varieties and composites from corn borer and weevil screening trials, Metro, FAW and IDRN crossed with Philippine DMRs and native DMR sources.

7. Corn-Borer-Weevil-DMR Comp. 2—white version of CB-W-DMR Comp. 1.

8. Early DMR Comp. 1—composed of advanced generation hybrids of native DMR varieties with early maturing introduced germplasm from Indonesia, India, Thailand and CIMMYT.

9. Early DMR Comp. 2—white version of early DMR Comp. 1.

10. Prolific DMR Comp. 1—composed mostly of advanced generation hybrids of prolific varieties from Southern USA and Philippine DMRs.

11. Prolific DMR Comp. 2—white version of Prolific DMR Comp. 1.

12. Brachytic DMR Comp.—composed of advanced generation hybrids of (Tuxpeño $br_2 \times$ promising introduced varieties) $\times$ native and Philippine DMRs. These were selected for modified dwarf character.

13. Philippine DMR Opaque Comp. 1—hard endosperm opaque selections from advanced generation hybrids of Yellow Hard Endosperm, Thai Opaque Comp. 1, College Opaque Comp. 2 with Philippine DMRs.

Results of 1974 wet season downy mildew test are presented in a frequency distribution table (Table 9). Philippine Composites 1 and 2 which were expected to already have high levels of resistance to downy mildew were inoculaated twice. The rest were inoculated only once. As expected, Philippine DMR Comp. 2 gave a high frequency of resistant families with a mean infection of 17.9 per cent. Philippine DMR Composite 1 gave more or less a normal distribution with a mean infection of 44.4 per cent, compared with the resistant check Philippine DMR 1 of 43.7 per cent. The data also suggest that the second inoculation was effective in increasing the infection rate as shown by the high mean infection of the susceptible check, UPCA VAR 1, in Philippine DMR Comp. 1 and 2 compared with those of the other populations.

Sixty families will be selected from each of these core populations and an average of 5 half-sib ears will be selected from each selected family to reconstitute a population of about 300 families for the succeeding cycle.

## Summary and Problems Ahead

1. Early efforts in breeding for downy mildew resistance resulted to the development of highly resistant inbred lines. These inbred lines have been extensively used as resistant sources during the later periods.

2. During th brief transition period that followed, massive screening of material showed that native germplasm is about the only good source of resistance to downy mildew in the Philippines.

3. The development of the Philippine DMRs and their subsequent release to farmers have provided a solution to the downy mildew problem in the Philippines. These and other promising advanced generation hybrids between native and introduced varieties developed during this period provide a very broad germplasm complex from which higher yield and downy mildew resistance levels maybe obtained.

4. This broad germplasm complex have been systematically grouped to form a number of composite populations. While emphasis will still be on downy mildew resistance and high yield, greater efforts are now exerted towards the solution of other problems which have been relegated to the background in the past.

5. Impovement in inoculation techniques in enhancing downy mildew epiphytotic conditions in the nursery have aided to a large extent the development of downy resistant germplasm. However, the discovery of the existence of oospores (Acedo and Exconde, 1967) means that there is a sexual cycle which would allow for selection and genetic

recombination for virulence in the pathogen. The implication of this to breeding for downy mildew resistance remains to be seen.

Large seasonal variations in downy mildew infection have been frequently observed in our nurseries even as progress in inoculation technique have been adopted. This may have been primarily due to the inadequacy of providing the optimum environment for disease development at all time.

Inoculation techniques should be perfected in order to raise the resistance threshold at much higher levels. More frequent inoculations and higher spore density or concentration in the spray suspension may help. Ullstrup (1973) suggested that use of surfactants or nutrients in the inoculum to increase efficiency in establishing infection should be explored.

6. The presence or absence of different physiological races is difficult to determine in the absence of specific DMR sources that can identify these. Genetic variance studies on downy mildew resistance, conducted in different locations and seasons may help. Significant location and genotype and season × genotype interactions may imply the existence of varying races. If such is the case, plant breeders may opt for the development of specific DMR varieties for specific locations or for the development of a variety with a broad resistance spectrum. This would require the establishment of a number of downy mildew screening nurseries in the country. An alternative method, which is somewhat dangerous, is to collect spores from different sources and dump them in a closely guarded and isolated screening nursery.

7. Lastly, the real and lasting benefit that can be derived from all these downy mildew resistance breeding efforts will be felt only when the inoculum potential is put down to such low ecological level in the farms that it ceases to be an important threat to corn production.

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## Question and Answer

**V. R. Carangal,** Philippines (Comment): The original name of the resistant variety developed by Mindanao Institute of Technology was MIT Sel-2. However, when the Philippine Seed Board approved the selection for distribution it was named at MIT UAR-2. So, the official name is MIT UAR-2.

**Joginder Singh,** India: 1) Do you have some information on the level of heritability of downy mildew resistance from your breeding programme?

2) How were your gains realized percycle from $S_1$ and mass selection programmes for downy mildew resistance programme?

**Answer:** None. As far as I can recall, there was no attempt to estimate heritability from data obtained in the progeny screening nurseries. To do this, data may have to be transformed first.

**Ampol Senanarong,** Thailand: 1) In your modified ear-to-row selection scheme, at what stage do you evaluate or select the families for downy mildew reaction?

2) What is the grain yield level of "MIT Sel-2" as compared to Phil. DMR #1 and Phil. DMR #3?

**Answer:** 1) We count the number of downy mildew infected plants as early as one month after emergence. We uproot the infected plants while counting. Plants that exhibit the symptoms later are similarly pulled and added to the previous tally. If we delay the counting there is the possibility of missing the plants that were infected at the early stages.

2) Yield of MIT Sel-2 is comparable to that of Philippine DMRs 1 and 3.